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(54) Dental composite and porcelain repair.

(57) A filled-resin composition useful for porcelain repair and as a dental composite and therefore made up of non-toxic materials and a method for repairing porcelain or teeth. The composition comprises a methacrylate functional resin usable in dental composites, powdered filler-colorant therein, at least one photoinitiator for the resin in an amount sufficient to initiate polymerization and complete it in depth within about half a minute when exposed to a visible-light output of at least 5,000 foot candles, the photoinitiator being an exciplex of (1) either 1,3-boronedione or benzil and (2) either ethyl-4-dimethyl amino benzoate or ethyl-2-dimethyl amino benzoate, and at least one accelerator-free peroxide curing agent for the resin in an effective amount for completing polymerization within about one-half hour of any portion of the resin not receiving sufficient light to effectuate complete cure before then. The method comprises mixing the components together under ordinary indoor lighting conditions, emplacing the mixture within a few minutes of the mixing, and curing at least a substantial portion of the emplaced mixture *in situ* for one half-minute under intense visible-light illumination of at least 5000 foot-candles. Any resin then uncured by light is cured within the next half hour by the peroxide curing agent.

DENTAL COMPOSITE AND PORCELAIN REPAIR

S P E C I F I C A T I O N

This invention relates to dental composites and porcelain repair material and to methods for making them.

Background of the Invention

Over the years many dental composites have been introduced, each composite possessing certain physical properties. However, substantially all of these dental composites can be categorized into two main groups, self-cured materials and light-cured materials.

The self-cured composites have involved free radical polymerization initiated by benzoyl peroxide (or another suitable peroxide) and accelerated, typically by a tertiary amine such as N,N-dimethyl-p-toluidine. The curing agents must be stored separately from the resin they are to cure, and they are mixed together just before use.

The light-cured composites have involved free radical polymerization initiated by the photoexcitation of light-sensitive compounds by ultraviolet or visible light. They are single-component systems, typically pastes, stored in opaque containers until the time of cure. Some of the photoinitiators that have been employed are the benzoin ethers, benzil ketals, dialkoxyacetophenones, benzophenones, thioxanthenes, and hydroxyalkylphenones.

In the practice of dentistry, some tooth repairs have been better achieved by self-cured composites and some have been better achieved by light-cured composites. While many factors have helped to determine whether a dentist would or should choose a self-cured material or a light-cured material, the prime factors have been working time, setting time, and the architecture of the cavity preparation.

1 The light-cured composites, combined with special
2 high-lumen lighting units employing fiber optics, have
3 offered variable working times and fast "snap" sets.
4 Setting can take between ten and forty seconds in many
5 instances. However, the use of light-cured composites has
6 been limited by the depth of the repair and the ease of
7 light penetration. Relatively unobstructed, clean, shallow
8 repair surfaces have been required. Visible-light-cured
9 materials have helped in solving some of the limitations
10 caused by repair depth, by roughly doubling the depths at
11 which cure is effective as compared to ultra-violet light-
12 cured material. Also, many dentists have felt more
13 comfortable using a visible, as opposed to an ultra-
14 violet, activating light source.

15 The amount of cure is variable and is a function
16 of exposure to lumens of visible light. These facts result
17 in extremely dangerous situations in many dental
18 restorations; because most dentists do not realize this
19 deficiency, because light-cured systems are advertised to
20 be able to be cured through tooth structure. In reality,
21 the situation is, at best, a gradient level of cure
22 obtained in relation to the amount of lumens of light
23 energy available to the restorative resin. That is to say,
24 layers close to the light source undergo greater percent
25 polymerization than the underlying layers. Consequently,
26 the incompletely polymerized restoration may wash out,
27 leak, or fail in adhesion. Yet the surface or bulk of the
28 restoration may appear clinically adequate, even though
29 new secondary decay may be beginning, and, because of its
30 concealment, result in death of the pulp or loss of the
31 tooth.

32 When a light-cured resin liner is used with a
33 light-cured paste composite at a depth of around 3 mm. or
34 greater, the resin liner may not cure because of
35 insufficient light reaching the resin. Uncured resin
36 liner can cause leaching, pulpal irritation, and loss of

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1 adhesion. Heretofore, the resin liner had, therefore, to
2 be polymerized prior to placement of the composite. With
3 this invention, such double cure is unnecessary.

4 Self-cured systems have offered assurance of
5 polymerization throughout the polymer mass used in any
6 repair surface architecture. However, their use has been
7 limited by manufacturer-determined work times and set
8 times. The peroxide and the accelerator could be adjusted
9 to give widely varying setting times; the quicker the set
10 time, the quicker the placement had to be made. Thus, in
11 order to give enough time for accurate placement, the set
12 times had to be longer than were desirable. Generally, set
13 times have been at least two or three minutes after mix,
14 and placement has had to be completed within forty-five
15 seconds after mix. This had made dentists work somewhat
16 faster than was desirable for many placements, and even
17 then the patient had to be immobilized longer than was
18 desirable before the composition set.

19 This invention overcomes the deficiencies of
20 light-cured systems, while preserving their functional
21 benefits. It also overcomes the deficiencies of the self-
22 cured systems by enabling quicker set times coupled with
23 longer placement times, if desired.

24 The system of this invention thus offers the best
25 properties of both types of curing systems without suffer-
26 ing from the limitations of either, and therefore it
27 significantly advances the practice of dentistry and the
28 science of dental materials.

29 The system of the present invention can be in a
30 powder-liquid, paste-paste, paste-powder, or gel-powder
31 form, so that there is no loss in versatility of possible
32 embodiments.

33 Similar problems occur with porcelain repair
34 systems in general, not only in dental uses, but for
35 repairing such porcelain articles as bathtubs, and the
36 invention solves these problems also.

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1 Summary of the Invention

2 This invention comprises a composite system
3 combining a small amount of peroxide curing agent, free
4 from accelerator, with certain photoinitiator systems
5 called exciplexes. A two-component system is required,
6 with mixture just before use. Conveniently, the resin and
7 its exciplex members can be stored in opaque (preferably
8 black) containers as one component, with or without some
9 of the filler. The peroxide is stored in a separate
10 component, including much or all of the filler-colorant,
11 in a container which need not be opaque. The two
12 components are mixed just prior to application, and there
13 is a wide latitude of mixing time, because no accelerator
14 is used. The curing effect of the peroxide in the resin is
15 quite slow, while the exposure of the resin and photo-
16 initiator exciplex members in ordinary light--whether
17 daylight or artificial light--will not result in
18 substantial curing. The time for placement is not
19 critical, because neither the photoinitiator exciplex nor
20 the peroxide causes quick curing at this stage. After
21 placement, a high-lumen light source is used with a fiber-
22 optics bundle to effect rapid cure (typically, ten to
23 forty seconds) down to a substantial depth. If the cavity
24 being filled is deeper than that depth, or if some of the
25 placed material has been shaded from the light or not
26 adequately illuminated, the light alone does not effect
27 sufficient cure. However, the cured deposit covering the
28 uncured material holds the uncured material in place, and
29 the peroxide has been found to effect cure of the uncured
30 material in about an hour, and usually in about half that
31 long.

32 To explain exciplexes: as in photoinitiator
33 systems generally, absorption of light by the ketone group
34 of some photoinitiators results in promotion of the
35 photoinitiator to a chemically reactive excited state;
36 alpha-cleavage results, and free radicals are formed. "In
37 the case of appropriate donor/acceptor systems,
38

1 interaction between an electronically excited molecule and
2 a ground-state molecule of another type may form an
3 excited-state complex, termed an 'exciplex'." Roffey, C.
4 G., Photopolymerization of Surface Coatings, p. 70, John
5 Wiley and Sons, Ltd., New York, 1982.

6 The incorporation of a suitable peroxide,
7 preferably benzoyl peroxide, with the photoinitiated
8 composite system has a synergistic effect on the free-
9 radical polymerization, resulting in uniform cure without
10 limitation after exposure to the activating light source.
11 The peroxide content is preferably about 0.05% to about
12 0.3% of the total composition.

13 The exciplex photoinitiators of this invention are
14 a combination of (1) either 2,3-bornanedione or benzil and
15 (2) either ethyl-4-dimethyl amino benzoate or ethyl-2-
16 dimethyl amino benzoate. The amount should be enough to
17 initiate polymerization in the selected resin and complete
18 it in depth within about half a minute when the filled-
19 resin composition is exposed to a visible-light output of
20 at least 5,000 foot candles. The peroxide should be
21 present in amount sufficient to complete, within about an
22 hour, the resin's polymerization, where it is not
23 completed by the photoinitiator-derived action, as where
24 the light never reaches the resin in the needed amount.

25 Thus, suitable photoinitiators for this invention
26 are the following exciplex-forming photoinitiators:

27
28 2,3-Bornanedione with ethyl-4-dimethyl amino
29 benzoate

30
31 2,3-Bornanedione with ethyl-2-dimethyl amino
32 benzoate

33
34 Benzil with ethyl-4-dimethyl amino benzoate

35
36 Benzil with ethyl-2-dimethyl amino benzoate.

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1 There are, of course, many other compounds capable
2 of photoinitiation. Many of these are taught in U.S.
3 4,222,835, to Dixon. However, Dixon's formulations were
4 intended for industrial fabrication, whereas the present
5 invention involves formulations which can be left in the
6 human mouth for many years. Consequently, compounds which
7 are known or are suspected to be toxic, carcinogenic,
8 teratogenic, mutagenic, etc. are not considered.

9 In addition there are those disclosed in our
10 earlier filed and co-pending application Serial Number
11 83 104316.1, filed 2 May 1983.

12 The present invention provides a much deeper cure
13 than do light-cured composites and obtains a much more
14 uniform degree of cure than do such systems. It obtains a
15 certainty of cure under overhangs, as opposed to prior-art
16 light-cured composites, and a more reliable cure through
17 tooth structure than the prior-art light-cured composites.
18 It provides more uniformity of cure, regardless of
19 exposure time or intensity. It provides better adhesion to
20 the teeth or to substrates such as porcelain as used in
21 dentistry and in plumbing fixtures, apparently due to more
22 complete polymerization. It has a longer shelf-life than
23 self-cured composites. It has better physical properties
24 than most prior-art light-cured composites, especially
25 lower water absorption.

26 It does not develop color bodies in composites
27 using chemically active glasses, such as strontium glass,
28 where some curing systems do develop objectionable color.
29 Moreover, the composite, when installed and cured in a
30 dental environment, looks like the tooth, not only in
31 ordinary light but also in ultra-violet light. In ultra-
32 violet light it fluoresces to substantially the same
33 degree as the tooth itself.

34 As stated above, the product is made up of two
35 separate formulations, one containing all or much of the
36 material to be cured along with the exciplex photoinitia-
37 tors. This formulation is kept from light, as in an
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1 opaque container. The other formulation contains the
2 peroxide curing agent, preferably along with any
3 ingredient not itself cured thereby, such as the filler-
4 colorants. In many instances (as in paste-paste systems)
5 it is preferred that the composition be so formulated that
6 equal amounts of the two formulations are mixed together
7 when they are to be used. In powder-liquid systems, there
8 is usually two to three and one-half as much powder as
9 liquid in each mixture.

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11 Description of Some Preferred Embodiments

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13 The binders or resins to be cured comprise
14 substantially all of those currently used in dental
15 composites. These are all methacrylate-functional resins.
16 Typical is ethoxylated bisphenol-A-dimethacrylate. Others
17 include Bis-GMA and the adducts disclosed in Waller's U.S.
18 Patent No. 3,629,187. Mixtures of resins may be used.
19 Waller's adducts are of 2-2'-propane bis [3-(4-phenoxy)-
20 1,2-hydroxy propane-1-methacrylate] and a mono- or di-
isocyanate.

21

22 The curing agents, as said, are of two types:
23 peroxides and photoinitiators. A suitable and preferred
24 peroxide is benzoyl peroxide. Some other peroxides are
25 either inoperable or have dangerous toxic side effects.

26

27 The photoinitiators are ordinarily in the same
28 component as the resin or gel, the resin-(or gel)-photo-
29 initiator exciplex components mixture being kept in opaque
30 containers until use. The peroxide is ordinarily kept
31 separate from the resin, usually with or upon the filler-
32 colorant or most of the filler-colorant. In paste-paste
systems, some of the resin may be in the same component as
the peroxide.

33

34 The suitable exciplex-forming photoinitiators are
the following:

35

36 2,3-Bornanedione with ethyl-4-dimethyl amino
37 benzoate

38

1 2,3-Bornanedione with ethyl-2-dimethyl amino
2 benzoate

3
4 Benzil with ethyl-4-dimethyl amino benzoate

5
6 Benzil with ethyl-2-dimethyl amino benzoate.

7
8 To the best of our knowledge, no one has
9 previously suggested that the combination of any of these
10 light-curing exciplex photoinitiators with any peroxide
11 could bring about better curing of these dental resins.
12 Likewise, it is not ordinary to utilize peroxide in such
13 small amounts as those utilized in this invention to
14 initiate polymerization of these resins. Furthermore,
15 peroxide curing agents are conventionally employed with
16 accelerators, and no accelerator is used here.
17 Consequently, the results obtained by this invention were
18 totally unexpected.

19 Practically all inert filler-colorants currently
20 used or usable in dental composites are usable herein.
21 Preferably, they are neither too coarse nor too fine. The
22 compositions employed in this invention may contain at
23 least about 10% by weight and up to about 90% by weight,
24 and preferably about 70-80% by weight, of a finely
25 divided, inert inorganic filler-colorant. The filler-
26 colorant, which may be in the form of spheres, platelets,
27 fibers, whiskers, or particles of any regular or irregular
28 shape and which preferably is transparent or translucent,
29 may comprise for example, apatite, soda glass, barium
30 glass, strontium glass, borosilicate glass, silica, fumed
31 silica, flint silica, alumina, quartz, lithium aluminum
32 silicate, or the like. Mixtures of more than one filler-
33 colorant may be used. The particle size of the filler-
34 colorant may range from about 0.005 to about 0.5 microns
35 in the case of microfine silica, to not greater than about
36 500 microns in the case of irregularly shaped particles.
37 Further, a range of particles sizes may be used. Where the

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1 filler-colorant is in the form of fibers, the maximum
2 dimension of the fibers preferably is not greater than
3 about 110 microns. On the other hand, where the filler-
4 colorant is in the form of spheres or platelets or is
5 irregularly shaped, the maximum dimension of the particles
6 preferably is not greater than about 350 microns.

7 The identity of the filler-colorant is not
8 critical, but barium-containing glass (hereinafter called
9 "barium glass"), strontium-containing glass (hereinafter
10 called "strontium glass"), lithium aluminum silicate,
11 flint silica, and fumed silica are excellent fillers and
12 mixtures of these are usually preferable to the use of
13 just one of them. For example, lithium aluminum silicate
14 has a negative heat coefficient of expansion, giving lower
15 overall thermal dimensional changes to the composite.
16 Barium and strontium glass impart opacity to X-rays. Flint
17 silica imparts tooth-like color, and fumed silica adjusts
18 viscosity and improves polishability.

19 One example of barium glass is Ray-Sorb T-2000, a
20 product of Kimble Division of Owens-Illinois Glass
21 Company. The same company makes Ray-Sorb T-4000, an
22 example of strontium glass.

23 Preferably, the peroxide is dispersed on the
24 filler-colorant powder, or by being dissolved in a
25 suitable solvent, is sprayed on the filler-colorant
26 powder, and the solvent evaporated. Preferably, the
27 peroxide is deposited in combination with a silane, such
28 as gamma-methacryloxy propyl trimethoxy silane (sold by
29 Union Carbide as A-174 silane), which is used to improve
30 bonding between the filler and the resin. The benzoyl
31 peroxide and the silane may be dissolved in methylene
32 chloride, chloroform, ether, or acetone, for example. Then
33 a slurry is made with the powdered filler-colorant; the
34 solvent is stripped off, leaving the silane and the
35 peroxide deposited on the dry powder filler-colorant.

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1 Glacial acetic acid is often used, in very small
2 amounts, because the hydrolysis reaction which attaches
3 the silane molecule to the filler-colorant particle is
4 carried out most effectively at a pH slightly less than
5 neutral.

6 Butylated hydroxytoluene is sometimes used in
7 order to scavenge small amounts of free radicals which can
8 form during extended shelf storage.

9 The invention can assume several forms: a powder-
10 liquid form, a paste-paste form, a paste-powder form, and
11 a gel-powder form. These forms will be considered in
12 order.

13
14 Powder-liquid systems

15 In general, the powder in this form comprises a
16 suitable filler-colorant material, a suitable silane, such
17 as gamma-methacryloxy propyl trimethoxy silane, and a
18 suitable peroxide curing agent such as benzoyl peroxide.
19 Preferably, these ingredients are in the following
20 approximate range of proportions by weight:

21

22 Powder

23

| 24 <u>Ingredients</u> | 25 <u>Percentage by Weight</u> |
|------------------------------------|--------------------------------|
| 26 Filler-colorant | 27 99.85 to 97.70% |
| 28 Silane | 29 0.10 to 1.55% |
| 30 Peroxide curing agent | 31 0.05 to 0.70% |
| 32 Glacial acetic acid | 33 0.00 to 0.05% |

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30 As stated above, the filler-colorant may be a mixture of
31 some or several of the filler-colorants listed above, or
32 it may be just one type of filler.

1 Liquid

| | | |
|---|---------------------------|-----------------------------|
| 2 | | |
| 3 | <u>Ingredients</u> | <u>Percentage by Weight</u> |
| 4 | Resin | 99.93 to 81.95% |
| 5 | Photoinitiator exciplex | 0.7 to 18% |
| 6 | Butylated hydroxy toluene | 0.00 to 0.05% |

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8 The formulae may be further generalized in a

9 somewhat more specific manner as follows: it being

10 understood that the various types of ingredients (e.g.,

11 filler-colorant, resin, etc.) will be used in quantities

12 that will total to the amounts just spelled out above:

13

14 Powder:

| | | |
|----|---------------------------|-----------------------------|
| 15 | | |
| 16 | <u>Ingredients</u> | <u>Percentage by Weight</u> |
| 17 | Barium glass | 0 to 30 |
| 18 | Lithium aluminum silicate | 0 to 99.85 |
| 19 | Flint silica | 0 to 10 |
| 20 | Borosilicate glass | 0 to 99.85 |
| 21 | Custer feldspar | 0 to 10.00 |
| 22 | Fumed synthetic silica | 0 to 99.85 |
| 23 | Quartz | 0 to 99.85 |
| 24 | Titanium dioxide | 0 to 0.15 |
| 25 | Tinting agents | |
| 26 | (e.g., iron oxides) | 0 to 5 |
| 27 | A-174 Silane | 0.1 to 1.55 |
| 28 | Peroxide curing agent | 0.05 to 0.70 |
| 29 | Glacial acetic acid | 0 to 0.05 |

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1 Liquid

| 3 | <u>Ingredients</u> | <u>Percentage by Weight</u> |
|----|---------------------------|-----------------------------|
| 4 | Bis-GMA | 0 to 80 |
| 5 | Ethoxylated bisphenol-A- | |
| 6 | dimethacrylate | 0 to 99.3 |
| 7 | Ethylene glycol | |
| 8 | dimethacrylate | 0 to 60 |
| 9 | Diethylene glycol | |
| 10 | dimethacrylate | 0 to 60 |
| 11 | Triethylene glycol | |
| 12 | dimethacrylate | 0 to 60 |
| 13 | Polyethylene glycol | |
| 14 | dimethacrylate | 0 to 60 |
| 15 | Photoinitiator (one or | |
| 16 | more from the exciplex | |
| 17 | list above) | 0.7 to 18 |
| 18 | Butylated hydroxy toluene | 0 to 0.05 |

19

20 Tinting agents are used to impart a more tooth-

21 like color. Red and yellow iron oxides are usually

22 employed.

23 Storage life for each mixture is very long, no

24 deterioration having been noticed so far over a period of

25 two and one-half years. The powder and the liquid are

26 mixed together in a ratio of weight from about 1:1 to

27 about 4:1 powder to liquid, just before they are needed.

28 Mixing may be accomplished on a paper mixing pad, with a

29 plastic instrument. Mixing may be done under normal room

30 lighting conditions, as found in the dental operatory,

31 illumination typically varying in intensity from about 80

32 to about 100 foot candles. Under these conditions, the

33 paste begins to gel after about 10 to 30 minutes,

34 depending on the particular formulations and

35 illuminations.

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1 When it is desired to initiate curing, the mixed
2 material is exposed to the output from a dental visible
3 light curing unit. For all examples cited herein, a Visar
4 curing light, marketed by Den-Mat, Inc., Santa Maria,
5 California, was used. This unit utilizes a type EKE or EJW
6 quartz-halogen light bulb, operating at 21 VAC. The light
7 is transmitted to the work site by a flexible fiber-optic
8 bundle, 1/4 inch in diameter by four feet in length. Other
9 units are available from other manufacturers. All are
10 similar in principle and results. Results of these
11 examples would be expected to differ only in degree if
12 other units were used. The output of the Visar unit used
13 is 180×10^4 Candella per square meter, giving illumina-
14 tion of about 20,000 foot candles on the material being
15 cured. Satisfactory operability can be achieved with 5,000
16 foot candles.

17 Under these conditions, the material cures in from
18 10 seconds to 30 seconds, with a cured depth of from 0.60
19 to 5.60 mm. Upon further standing, that is, from 5 minutes
20 to 35 minutes, the material exhibits a cure depth of
21 greater than 12 mm. It shows a tensile strength, measured
22 by the diametral method on samples 6 mm diameter by 3 mm
23 high, of between 4800 psi and 7000 psi. A popular prior-
24 art, light-cured dental composite, when tested in
25 identical fashion, showed a cure depth of 3.05 mm
26 immediately after exposure to the curing light, but this
27 cure depth did not increase over a period of 16 hours
28 after cure, and its diametral tensile strength was only
29 2030 psi.

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1 EXAMPLE 1

2
3 Powder-Liquid System

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5 Powder:

| 6 <u>Ingredients</u> | Percentage by Weight |
|-----------------------------|----------------------|
| 7 Barium glass | 28.63% |
| 8 Lithium aluminum silicate | 67.84% |
| 9 Flint silica | 2.84% |
| 10 Benzoyl peroxide | 0.20% |
| 11 A-174 silane | 0.47% |
| 12 Glacial acetic acid | 0.02% |

13
14 A-174 silane is a Union Carbide product,
15 chemically gamma-methacryloxy propyl trimethoxy silane.
16 The barium glass may be Ray-Sorb T-2000, a product of
17 Kimble Division of Owens-Illinois Glass Company or may be
18 barium aluminum silicate.

19
20 Liquid

| 21 <u>Ingredients</u> | Percentage by Weight |
|-----------------------------|----------------------|
| 22 Ethoxylated bisphenol-A- | |
| 23 dimethacrylate | 95.53% |
| 24 2,3-Bornanedione | 0.17% |
| 25 Ethyl-4-dimethylamino- | |
| 26 benzoate | 4.30% |

27
28 The powder and the liquid were mixed together,
29 preferably in a ratio by weight of about 2:1 to about
30 3-1/2:1, powder to liquid, just before they were needed.
31 Mixing took about twenty seconds. The mixtures are
32 preferably applied within about five minutes. The setting
33 time was about twenty minutes when not exposed to a dental
34 curing light, but was less than thirty seconds on exposure
35 to a dental curing light. The result was a hard filling.

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1 EXAMPLE 2

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3 Hardness comparisons with some prior-art systems:

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5 A disk of a commercially available light-curable
6 dental composite was prepared, 20 mm diameter by 1 mm
7 thick. One-half of this disk was shaded with aluminum
8 foil, and the disk then was placed under a photoflood lamp
9 for 15 minutes. The sample was removed from under the
10 lamp, the foil removed from the sample, and Barcol
11 hardness measured on both the shaded and unshaded halves.
12 The unshaded half showed a Barcol hardness of 82, while
13 the shaded side had a Barcol hardness reading of less than
14 1. This same experiment was performed on a disk made of
15 the mixed but uncured material of Example 1, and both
16 sides of both disks showed a Barcol hardness of 92.
17

18 EXAMPLE 3

19
20 Comparison of degree of cure:

21
22 A series of tests was performed on several
23 commercially-available light-curing composites to
24 determine the degree of cure of the resin matrix. Testing
25 was accomplished by preparing duplicate samples, 1 mm
26 thick by 40 mm in diameter. These samples were cured by
27 exposing them to a photoflood lamp for 30 minutes, and
28 then they were placed in 37°C. water for 24 hours. The
29 samples were then dried, and placed in a desiccator and
30 weighted daily until constant weight (± 0.5 mg.) was
31 achieved. The samples were then granulated, placed in a
32 glass thimble and extracted for 12 hours in a Soxhlett
33 extraction apparatus with methylene chloride. After
34 extraction, the samples were weighted and the weight loss
35 converted to percent uncured monomer removed.
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1 When two popular commercially-available light-
2 cured dental composites were tested in this manner, the
3 cured product contained 3.08% and 5.26% extractables,
4 representative of the amount of uncured monomer.

5 The material of Example 1 of this invention, when
6 tested in the same manner, contained only 1.87%
7 extractables, showing a much higher degree of cure.

8
9 EXAMPLE 4

10
11 Comparison of degree of water sorption:

12
13 A series of three light-cured dental restoratives
14 were tested in order to determine the degree of water
15 sorption. Samples were in duplicate, and were configured
16 and tested in accordance with American Dental Association
17 Specification No. 27.

18 Two popular commercially-available light-cured
19 dental restoratives were found to have water sorption
20 values of 1.05 and 0.95 mg/cm², respectively. The material
21 of Example 1 gave a value of only 0.86 mg/cm².

22
23 EXAMPLE 5

24
25 Powder-liquid system of porcelain repair:

26
27 The powder-liquid system of Example 1 was tested
28 as a porcelain repair material, as described in U.S.
29 Patent No. 4,117,595.

30 A commercially available material marketed to
31 practice the above-mentioned patent had test results of
32 2015 psi bond strength (average of 5 samples) when tested
33 7 days after preparation, being stored meantime in water
34 at 37°C.

35 The material of Example 1, when tested in the same
36 fashion, with the same test equipment, gave results of
37 2400 psi bond strength or 26.6% higher.

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1 EXAMPLE 6

2

3 Comparison with a conventional powder-liquid system
4 (using larger amounts of benzoyl peroxide than this
5 system):

6

7 Powder:

| 8 <u>Ingredients</u> | <u>Percentage by Weight</u> |
|----------------------|-----------------------------|
| 9 Strontium glass | |
| 10 (Ray-sorb T-4000) | 95.69% |
| 11 A-174 Silane | 1.44% |
| 12 Benzoyl peroxide | 2.87% |

13

14 Liquid:

| 15 <u>Ingredients</u> | <u>Percentage by Weight</u> |
|-----------------------------|-----------------------------|
| 16 Ethoxylated bisphenol-A- | |
| 17 dimethacrylate | 77.21% |
| 18 Triethylene glycol | |
| 19 dimethacrylate | 19.31% |
| 20 1-Hydroxy-4-methoxy- | |
| 21 benzophenone | 1.93% |
| 22 Butylated hydroxytoluene | 0.05% |
| 23 N,N-2-hydroxyethyl-p- | |
| 24 toluidine | 1.50%. |

25

26 The powder and liquid were mixed in a weight ratio
27 of 3:1 of powder to liquid and cured properly. However, a
28 bright green color was formed on curing. The mixture was
29 repeated after acid-washing the strontium glass, but the
30 green color persisted. The mixture was again repeated
31 using N,N-3,5-tetramethylalanine as a substitute for the
32 N,N-2-hydroxyethyl-p-toluidine. Again the green color
33 developed.

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1 The mixture was repeated once again using
2 N,N-dimethyl-p-toluidine as activator instead of the
3 N,N-2-hydroxyethyl-p-toluidine. This time the green color
4 did not develop, but the curing characteristics of the
5 composite degraded.

6 Then the experiment was repeated, using the
7 following powder and liquid:

8
9 Powder:

| <u>Ingredients</u> | <u>Percentage by Weight</u> |
|--------------------|-----------------------------|
| Strontium glass | |
| (Ray-sorb T-4000) | 98.300% |
| A-174 Silane | 1.475% |
| Benzoyl peroxide | 0.200% |
| Acetic acid | 0.025% |

16
17 Liquid:

| <u>Ingredients</u> | <u>Percentage by Weight</u> |
|--------------------------|-----------------------------|
| Ethoxylated bisphenol-A- | |
| dimethacrylate | 76.41% |
| Triethylene glycol | |
| dimethacrylate | 19.10% |
| 2,3-Bornanediol | 0.17% |
| Ethyl 4-dimethyl amino | |
| benzoate | 4.30% |
| Butylated hydroxytoluene | 0.02% |

28
29 No color developed, the material cured satisfactorily
30 under the output from a Visar dental curing light, and
31 exhibited a depth of cure of 5.20 mm immediately after
32 exposure to the light, and 12 mm depth of cure after 30
33 minutes. Diametral tensile strength was 6000 psi.

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1 EXAMPLE 7

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3 Powder-Liquid System

4

5 Powder:

| 6 | <u>Ingredients</u> | <u>Percentage by Weight</u> |
|----|---------------------------|-----------------------------|
| 7 | Barium glass | 28.63% |
| 8 | Lithium aluminum silicate | 66.80% |
| 9 | Flint silica | 2.84% |
| 10 | Benzoyl peroxide | 0.20% |
| 11 | A-174 silane | 1.51% |
| 12 | Glacial acetic acid | 0.02% |

13

14

15 Liquid

| 16 | <u>Ingredients</u> | <u>Percentage by Weight</u> |
|----|--------------------------|-----------------------------|
| 17 | Ethoxylated bisphenol-A- | |
| 18 | dimethacrylate | 95.53% |
| 19 | 2,3-Bornanedione | 0.17% |
| 20 | Ethyl-4-dimethylamino- | |
| 21 | benzoate | 4.30% |

22

23 Again, the powder and liquid were mixed together
 24 in a weight ratios varying from about 2:1 to about 3-1/2:1,
 25 powder to liquid. Curing time was 30 seconds with a depth
 26 of 5.50 mm when exposed to a visible light dental curing
 27 unit. Diametral tensile strength was 6500 psi. The paste
 28 had a workable time of 30 minutes under normal room
 29 fluorescent lighting.

30

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1 EXAMPLE 8

2

3 Powder-Liquid System

4

5 Powder:

| 6 <u>Ingredients</u> | <u>Percentage by Weight</u> |
|-----------------------------|-----------------------------|
| 7 Lithium aluminum silicate | 66.80% |
| 8 Barium glass | 28.63% |
| 9 Flint silica | 2.84% |
| 10 Benzoyl peroxide | 0.20% |
| 11 A-174 silane | 1.51% |
| 12 Glacial acetic acid | 0.02% |

13

14

15 Liquid

| 16 <u>Ingredients</u> | <u>Percentage by Weight</u> |
|---------------------------|-----------------------------|
| 17 Bis-GMA, i.e., | |
| 18 2,2'-propane-bis- | |
| 19 [3-(4-phenoxy)-1,2- | |
| 20 hydroxy propane-1- | |
| 21 methacrylate] | 57.40% |
| 22 Triethylene glycol | |
| 23 dimethacrylate | 37.94 |
| 24 2,3-Bornanediol | 0.02% |
| 25 Ethyl-4-dimethylamino- | |
| 26 benzoate | 4.64% |

27

28 Three parts of the powder and one part of the
29 liquid were mixed together to form a paste. This paste,
30 when exposed to a visible light dental curing unit for 30
31 seconds, cured to a depth of 5.40 mm. Under normal room
32 fluorescent lighting, the paste had a workable time of
33 approximately 20 minutes. The diametral tensile strength
34 was 6900 psi.

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1 EXAMPLE 9

2

3 Powder-Liquid System

4

5 Powder:

6 Ingredients

Percentage by Weight

| | | |
|----|---------------------------|--------|
| 7 | Lithium aluminum silicate | 66.80% |
| 8 | Barium glass | 28.63% |
| 9 | Flint silica | 2.84% |
| 10 | Benzoyl peroxide | 0.20% |
| 11 | A-174 silane | 1.51% |
| 12 | Glacial acetic acid | 0.02% |

13

14

15 Liquid

16 Ingredients

Percentage by Weight

| | | |
|----|--------------------------|--------|
| 17 | Ethoxylated bisphenol-A- | |
| 18 | dimethacrylate | 75.98% |
| 19 | Triethylene glycol | |
| 20 | dimethacrylate | 19.36% |
| 21 | 2,3-Bornanediol | 0.02% |
| 22 | Ethyl-4-dimethylamino- | |
| 23 | benzoate | 4.64% |

24

25 Three parts of the powder and one part of the liquid were
 26 mixed together to form a paste. This paste, when exposed
 27 to the output from a Visar dental visible light curing
 28 unit for 30 seconds, cured to a depth of 5.30 mm. When
 29 left exposed to room fluorescent lighting, the paste had a
 30 working time of about 40 minutes and a diametral tensile
 31 strength of 6940 psi.

32

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1 EXAMPLE 10

2 A comparison of curing of various powder/liquid
3 systems utilizing different exciplex-forming photo-
4 initiators

5
6 A series of resin blends was prepared, all as
7 indicated below as resins A-N, where all the percentages
8 of ingredients are given by weight. Also a standard blend
9 of powder was prepared. Benzoyl peroxide was added to the
10 powder in different levels. The resultant powders were
11 mixed with the resin blends and exposed to the output from
12 a Visar dental curing light for 30 seconds, and the depth
13 of cure measurement was taken.

14 As controls resin blends were made without one or
15 all of the exciplex members.

16 On some of these samples, glass tubes 12 mm long
17 were filled with the test material, and were wrapped with
18 black vinyl tape to exclude light for 30 seconds, then the
19 time was measured until the material at the opposite end
20 of the tube was cured. This test will be referred to as
21 the "Infinite Depth of Cure Test" in the following text.

22 As a control, a popular commercially available
23 light-cured composite was tested in the same manner. It
24 initially cured in 30 seconds to a depth of 3.05 mm, and
25 there was no increase in cure depth when measured after 16
26 hours.

27

28 Standard Blend of Powder

29

| | | |
|----|---------------------------|--------|
| 30 | Barium glass | 29.54% |
| 31 | Lithium aluminum silicate | 68.96% |
| 32 | A-174 silane | 1.48% |
| 33 | Glacial acetic acid | 0.02% |

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1 Resin A:

| | | |
|---|--------------------------|---------|
| 2 | Ethoxylated bisphenol-A- | |
| 3 | dimethacrylate | 100.00% |
| 4 | | |

5 Resin A was mixed in a ratio of 1:2 with a powder blend
6 containing 0.61% added benzoyl peroxide. No cure was
7 observed.

9 Resin B:

| | | |
|----|--------------------------|--------|
| 10 | Ethoxylated bisphenol-A- | |
| 11 | dimethacrylate | 95.53% |
| 12 | 2,3-Bornanedione | 0.17% |
| 13 | Ethyl-4-dimethylamino- | |
| 14 | benzoate | 4.30% |
| 15 | | |

16 Resin B was mixed in a ratio of 1:3 with powder blends
17 containing 0.20 and 0.22% added benzoyl peroxide. The cure
18 depths observed were both 5.50 mm. The time in minutes
19 after light exposure for "infinite cure" of the blend made
20 with the 0.22% added peroxide was 30.

22 Resin C:

| | | |
|----|--------------------------|--------|
| 23 | Ethoxylated bisphenol-A- | |
| 24 | dimethacrylate | 91.70% |
| 25 | Benzoin methyl ether | 8.30% |
| 26 | | |

27 Resin C was mixed in a ratio of 1:3 with a powder blend
28 containing 0.20% added benzoyl peroxide. The cure depth
29 was 1.32 mm. There was no subsequent increase in cure
30 depth.

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1 Resin D:

| | | |
|---|--------------------------|--------|
| 2 | Ethoxylated bisphenol-A- | |
| 3 | dimethacrylate | 84.60% |
| 4 | Benzoin methyl ether | 7.70% |
| 5 | Ethyl-4-dimethylamino- | |
| 6 | benzoate | 7.70% |

7
8 Resin D was mixed in a ratio of 1:3 with a powder blend
9 containing 0.20% added benzoyl peroxide. The cure depth
10 was 2.55 mm. The time in minutes after light exposure for
11 "infinite cure" of the blend was 60.

12

13 Resin E:

| | | |
|----|--------------------------|--------|
| 14 | Ethoxylated bisphenol-A- | |
| 15 | dimethacrylate | 82.30% |
| 16 | Benzoin methyl ether | 7.70% |
| 17 | Ethyl-2-dimethylamino- | |
| 18 | benzoate | 10.00 |

19

20 Resin E was mixed in a ratio of 1:3 with a powder blend
21 containing 0.20% added benzoyl peroxide. The cure depth
22 was 2.65 mm. The time in minutes after light exposure for
23 "infinite cure" of the blend was 45.

24

25 Resin F:

| | | |
|----|--------------------------|--------|
| 26 | Ethoxylated bisphenol-A- | |
| 27 | dimethacrylate | 86.60% |
| 28 | Benzoin methyl ether | 3.40% |
| 29 | Ethyl-2-dimethylamino- | |
| 30 | benzoate | 10.00 |

31

32 Resin F was mixed in a ratio of 1:3 with a powder blend
33 containing 0.20% added benzoyl peroxide. The cure depth
34 was 2.74 mm. The time in minutes after light exposure for
35 "infinite cure" of the blend was 60.

36

37

38

1 Resin G:

| | | |
|---|--------------------------|--------|
| 2 | Ethoxylated bisphenol-A- | |
| 3 | dimethacrylate | 88.80% |
| 4 | Benzoin methyl ether | 3.50% |
| 5 | Ethyl-4-dimethylamino- | |
| 6 | benzoate | 7.70% |

7
8 Resin G was mixed in a ratio of 1:3 with a powder blend
9 containing 0.20% added benzoyl peroxide. The cure depth
10 was 3.53 mm. The time in minutes after light exposure for
11 "infinite cure" of the blend was 50.

12
13 Resin H:

| | | |
|----|--------------------------|--------|
| 14 | Ethoxylated bisphenol-A- | |
| 15 | dimethacrylate | 91.70% |
| 16 | Benzil | 8.30% |

17
18 Resin H was mixed in a ratio of 1:3 with a powder blend
19 containing 0.20% added benzoyl peroxide. The cure depth
20 was 4.06 mm. There was no subsequent increase in the depth
21 of cure.

22
23 Resin I:

| | | |
|----|--------------------------|--------|
| 24 | Ethoxylated bisphenol-A- | |
| 25 | dimethacrylate | 84.60% |
| 26 | Benzil | 7.70% |
| 27 | Ethyl-4-dimethylamino- | |
| 28 | benzoate | 7.70% |

29
30 Resin I was mixed in a ratio of 1:3 with a powder blend
31 containing 0.20% added benzoyl peroxide. The cure depth
32 was 4.84 mm. The time in minutes after light exposure for
33 "infinite cure" of the blend was 25.

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1 Resin J:

| | | |
|---|--------------------------|--------|
| 2 | Ethoxylated bisphenol-A- | |
| 3 | dimethacrylate | 84.60% |
| 4 | Benzil | 7.70% |
| 5 | Ethyl-2-dimethylamino- | |
| 6 | benzoate | 7.70% |

7
8 Resin J was mixed in a ratio of 1:3 with a powder blend
9 containing 0.20% added benzoyl peroxide. The cure depth
10 was 5.02 mm. The time in minutes after light exposure for
11 "infinite cure" of the blend was 25.

12
13 Resin K:

| | | |
|----|--------------------------|--------|
| 14 | Ethoxylated bisphenol-A- | |
| 15 | dimethacrylate | 91.50% |
| 16 | 2,3-Bornanediene | 0.17% |
| 17 | Ethyl-2-dimethylamino- | |
| 18 | benzoate | 8.33% |

19
20 Resin K was mixed in a ratio of 1:3 with a powder blend
21 containing 0.20% added benzoyl peroxide. The cure depth
22 was 5.56 mm. The time in minutes after light exposure for
23 "infinite cure" of the blend was 60.

24
25 Resin L:

| | | |
|----|--------------------------|--------|
| 26 | Ethoxylated bisphenol-A- | |
| 27 | dimethacrylate | 88.80% |
| 28 | Dibenzyl ketone | 3.40 |
| 29 | Ethyl-4-dimethylamino- | |
| 30 | benzoate | 7.80% |

31
32 Resin L was mixed in a ratio of 1:3 with a powder blend
33 containing 0.20% added benzoyl peroxide. The cure depth
34 was 1.87 mm. The time in minutes after light exposure for
35 "infinite cure" of the blend was 45 minutes.

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1 Resin M:

| | | |
|---|--------------------------|--------|
| 2 | Ethoxylated bisphenol-A- | |
| 3 | dimethacrylate | 86.60% |
| 4 | Dibenzyl ketone | 3.40% |
| 5 | Ethyl-2-dimethylamino- | |
| 6 | benzoate | 10.00% |

7
8 Resin M was mixed in a ratio of 1:3 with a powder blend
9 containing 0.20% added benzoyl peroxide. The cure depth
10 was 0.84 mm. The time in minutes after light exposure for
11 "infinite cure" of the blend was 50 minutes.

12

13 Resin N:

| | | |
|----|--------------------------|--------|
| 14 | Ethoxylated bisphenol-A- | |
| 15 | dimethacrylate | 96.60% |
| 16 | Dibenzyl ketone | 3.40% |

17

18 Resin N was mixed in a ratio of 1:3 with a powder blend
19 containing 0.20% added benzoyl peroxide. The cure depth
20 was 1.55 mm. The time in minutes after light exposure for
21 "infinite cure" of the blend was 52 minutes.

22

23

24 Paste-Paste Systems

25 Some dentists (and perhaps other users) prefer to
26 work with pastes: most of these users also prefer to use
27 equal amounts of the two pastes, so that paste-paste
28 systems are usually formulated to enable use of equal
29 amounts.

30 In general, the paste-paste system of the present
31 invention may be formulated as follows:

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1 Paste A:

| 2 | | <u>Percentage by Weight</u> | |
|---|--------------------------|-----------------------------|----------|
| 3 | <u>Ingredients</u> | | |
| 4 | Resin | 14 | to 39.63 |
| 5 | Filler-colorant | 84.68 | to 59.46 |
| 6 | Peroxide | 0.10 | to 0.75 |
| 7 | A-174 silane | 1.21 | to 0.06 |
| 8 | Butylated hydroxytoluene | 0.01 | to 0.10 |

10 Paste B:

| 11 | | <u>Percentage by Weight</u> | |
|----|---------------------|-----------------------------|----------|
| 12 | <u>Ingredients</u> | | |
| 13 | Resin | 14 | to 35.43 |
| 14 | Filler-colorant | 83.24 | to 53.17 |
| 15 | Exciplex forming | 1.5 | to 3.5 |
| 16 | photoinitiator | 1.21 | to 0.05 |
| 17 | A-174 silane | 0.05 | to 0.01 |
| 18 | Glacial acetic acid | | |

19
20 The two pastes are preferably mixed in equal
21 amounts. Mixing time, working time, and setting time are
22 approximately the same as for the powder-liquid systems,
23 described above, and the results in cure and hardness are
24 approximately the same, too. Again, ordinary room lighting
25 has little curing effect. The resin may be the same in
26 both pastes, as may the filler. The silane is preferably
27 deposited on the filler of both pastes prior to making the
28 pastes. The presence of both resin and peroxide in Paste A
29 seems not to effect a cure nor to affect substantially the
30 storage life.

31 More specifically considered, the paste-paste
32 system employs the following formulations:

33
34
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37

| | | |
|----|--|--------------------------|
| 1 | <u>Paste A:</u> | |
| 2 | <u>Ingredients</u> | <u>Percent by Weight</u> |
| 3 | Bis-GMA | 0 to 32 |
| 4 | Ethoxylated bisphenol-A-dimethacrylate | 0 to 40 |
| 5 | Ethylene glycol dimethacrylate | 0 to 24 |
| 6 | Diethylene glycol dimethacrylate | 0 to 24 |
| 7 | Triethylene glycol dimethacrylate | 0 to 24 |
| 8 | Polyethylene glycol dimethacrylate | 0 to 24 |
| 9 | Barium glass | 0 to 25 |
| 10 | Lithium aluminum silicate | 0 to 85 |
| 11 | Flint silica | 0 to 8.5 |
| 12 | Borosilicate glass | 0 to 85 |
| 13 | Fumed synthetic silica | 0 to 52 |
| 14 | Quartz | 0 to 85 |
| 15 | Strontium glass | 0 to 85 |
| 16 | Titanium dioxide | 0 to 0.13 |
| 17 | Tinting agents (e.g., iron oxides) | 0 to 4 |
| 18 | A-174 Silane | 0.06 to 1.21 |
| 19 | Peroxide curing agent | 0.10 to 0.75 |
| 20 | Butylated hydroxy toluene | 0.01 to 0.1 |
| 21 | | |
| 22 | | |
| 23 | | |
| 24 | | |
| 25 | | |
| 26 | | |
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| | | |
|----|--|-------------------|
| 1 | <u>Paste B:</u> | |
| 2 | Ingredients | Percent by Weight |
| 3 | Bis-GMA | 0 to 32 |
| 4 | Ethoxylated bisphenol-A-dimethacrylate | 0 to 40 |
| 5 | Ethylene glycol dimethacrylate | 0 to 24 |
| 6 | Diethylene glycol dimethacrylate | 0 to 24 |
| 7 | Triethylene glycol dimethacrylate | 0 to 24 |
| 8 | Polyethylene glycol dimethacrylate | 0 to 24 |
| 9 | Barium glass | 0 to 25 |
| 10 | Lithium aluminum silicate | 0 to 85 |
| 11 | Flint silica | 0 to 8.5 |
| 12 | Borosilicate glass | 0 to 85 |
| 13 | Fumed synthetic silica | 0 to 52 |
| 14 | Quartz | 0 to 85 |
| 15 | Strontium glass | 0 to 85 |
| 16 | Titanium dioxide | 0 to 0.13 |
| 17 | Tinting agents (e.g., iron oxides) | 0 to 4 |
| 18 | A-174 Silane | 0.05 to 1.21 |
| 19 | Exciplex-forming-photoinitiator | 1.5 to 3.5 |
| 20 | Glacial acetic acid | 0.01 to 0.05 |

21
22 This formulation should be read with the more
23 general one preceding it, to supply the percentages of
24 fillers, resins, and silane needed, along with appropriate
25 amounts of the curing agents. All percentages are by
26 weight.

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1 EXAMPLE 112 Paste-Paste System

3

4 Paste A:5 Ingredients Percentage by Weight

| | | |
|----|---------------------------|--------|
| 6 | Ethoxylated bisphenol-A- | |
| 7 | dimethacrylate | 17.66% |
| 8 | Benzoyl peroxide | 0.30% |
| 9 | Butylated hydroxytoluene | 0.04% |
| 10 | Barium glass | 24.25% |
| 11 | Lithium aluminum silicate | 56.43% |
| 12 | Fumed silica | 0.92% |
| 13 | A-174 silane | 0.40% |

14

15 The fumed silica may be Aerosil 200 of Degussa Corp. of
16 Teterboro, New Jersey.

17

18 Paste B:19 Ingredients Percentage by Weight

| | | |
|----|---------------------------|---------|
| 20 | Ethoxylated bisphenol-A- | |
| 21 | dimethacrylate | 14.94% |
| 22 | 2,3-Bornanediene | 0.06% |
| 23 | Ethyl-4-dimethylamino | |
| 24 | benzoate | 1.55% |
| 25 | Barium glass | 24.394% |
| 26 | Lithium aluminum silicate | 56.92% |
| 27 | Fumed silica | 0.92% |
| 28 | A-174 silane | 1.2% |
| 29 | Glacial acetic acid | 0.016% |

30

31 The two pastes are preferably mixed in equal
32 quantities just before application and are cured by a
33 dental curing light, such as Visar, or equivalent. When so
34 mixed and exposed to a visible light curing unit for 30
35 seconds, the material cured to a depth of 5.43 mm. The
36 diametral tensile strength was 6990 psi.

37

38

1 EXAMPLE 12

2

3 Paste A:

| 4 <u>Ingredients</u> | <u>Percentage by Weight</u> |
|----------------------------|-----------------------------|
| 5 Ethoxylated bisphenol-A- | |
| 6 dimethacrylate | 17.66% |
| 7 Benzoyl peroxide | 0.30% |
| 8 Butylated hydroxytoluene | 0.04% |
| 9 Strontium glass | 79.88% |
| 10 Fumed silica | 0.92% |
| 11 A-174 silane | 1.20% |

12

13

14 The strontium glass may be Ray-sorb T-4000 of
15 Kimble Division of Owens-Illinois.

16

17 Paste B:

| 18 <u>Ingredients</u> | <u>Percentage by Weight</u> |
|-----------------------------|-----------------------------|
| 19 Ethoxylated bisphenol-A- | |
| 20 dimethacrylate | 14.94% |
| 21 2,3-Bornanediol | 0.06% |
| 22 Ethyl-4-dimethylamino | |
| 23 benzoate | 1.55% |
| 24 Strontium glass | 81.3284% |
| 25 Fumed silica | 0.92% |
| 26 A-174 silane | 1.20% |
| 27 Glacial acetic acid | 0.0016% |

28

29 Equal or substantially equal amounts of pastes A
30 and B are mixed together just before use. When so mixed
31 and exposed to a visible light curing unit for 30 seconds,
32 the material cured to a depth of 5.50 mm. The diametral
33 tensile strength was 4790 psi.

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1 EXAMPLE 13

2 The pastes from Examples 11 and 12, mixed in equal
3 parts, were exposed to the output from a Visar dental
4 curing unit for 30 seconds. The samples were tested to
5 determine the time required to achieve a 12 mm (or
6 "infinite") depth of cure. The samples were tested as
7 described previously. Pastes A and B of Example 11 when
8 mixed together obtained "infinite" cure in 35 minutes.
9 Pastes A and B of examples 12 when mixed together obtained
10 "infinite" cure in 35 minutes.

11

12 Paste-Powder Systems

13 A third type of system is somewhat of a blend
14 between the powder-liquid system and the paste-paste
15 system. Here, the powder remains substantially the same as
16 in the powder-liquid system, except that it has a larger
17 percentage of peroxide. However, the paste contains the
18 exciplex-forming members dissolved in a liquid resin, and
19 the filler, suspended therein. This paste material should
20 be stored in a light-free container. Typically, a black
21 polyethylene or polypropylene syringe may be used as the
22 container, as in the paste-paste systems.

23 The powder is coated with a suitable silane, such
24 as gamma methacryloxy propyl trimethoxy silane, and has
25 benzoyl peroxide dispersed over its surface. This
26 component may be stored in a container suited to dispers-
27 ing small amounts. A small cylindrical plastic vial with a
28 small orificed dropper tip is preferred.

29 In practice, an amount of the paste is expressed
30 onto a mixing pad, then a very small amount--1/10 to
31 1/20-- of the powder is mixed in; so the powder has more
32 peroxide in it than in previous systems discussed. The
33 result is that the paste is thickened--a condition desired
34 by some dentists--and also that depth of cure and cure
35 efficiency are improved.

36 A general formulation may be expressed as follows:

37

38

1 Paste:

| 2 | <u>Ingredients</u> | <u>Percentage by Weight</u> |
|---|---------------------|-----------------------------|
| 3 | Resin | 13.00 to 63.4 |
| 4 | Filler-colorant | 84.78 to 32.85 |
| 5 | Exciplex-forming | |
| 6 | photoinitiators | 0.7 to 3.696 |
| 7 | A-174 silane | 1.50 to 0.05 |
| 8 | Glacial acetic acid | 0.02 to 0.004 |

10 Powder:

| 11 | <u>Ingredients</u> | <u>Percentage by Weight</u> |
|----|---------------------|-----------------------------|
| 12 | Filler-colorant | 99.58 to 83.83 |
| 13 | A-174 silane | 0.10 to 6 |
| 14 | Peroxide | 0.30 to 10.00 |
| 15 | Glacial acetic acid | 0.02 to 0.17 |

17 The mixture is preferably done in a ratio varying
18 between 20 to 1 of paste to powder to 10 to 1 of paste to
19 powder. More specifically, this system may comprise the
20 following, with resin, filler, etc., ingredients always
21 lying within the above-given ranges and percentages being
22 by weight:

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| | | | |
|----|------------------------------------|--------------------------|----------|
| 1 | <u>Paste:</u> | | |
| 2 | <u>Ingredients</u> | <u>Percent by Weight</u> | |
| 3 | Bis-GMA | 0 | to 32 |
| 4 | Ethoxylated bisphenol-A- | | |
| 5 | dimethacrylate | 0 | to 63.4 |
| 6 | Ethylene glycol dimethacrylate | 0 | to 24 |
| 7 | Diethylene glycol dimethacrylate | 0 | to 24 |
| 8 | Triethylene glycol dimethacrylate | 0 | to 24 |
| 9 | Polyethylene glycol dimethacrylate | 0 | to 24 |
| 10 | Barium glass | 0 | to 25 |
| 11 | Lithium aluminum silicate | 0 | to 85 |
| 12 | Flint silica | | to 8.5 |
| 13 | Borosilicate glass | 0 | to 85 |
| 14 | Fumed synthetic silica | 0 | to 52 |
| 15 | Strontium glass | 0 | to 85 |
| 16 | Quartz | 0 | to 85 |
| 17 | Titanium dioxide | 0 | to 0.13 |
| 18 | Tinting agents (e.g., iron oxides) | 0 | to 4 |
| 19 | A-174 Silane | 0.05 | to 1.25 |
| 20 | Exciplex-forming photoinitiators | 0.7 | to 3.70 |
| 21 | Glacial acetic acid | 0.004 | to 0.02 |
| 22 | | | |
| 23 | <u>Powder:</u> | | |
| 24 | <u>Ingredients</u> | <u>Percent by Weight</u> | |
| 25 | | | |
| 26 | Barium glass | 0 | to 30 |
| 27 | Lithium aluminum silicate | 0 | to 99.65 |
| 28 | Flint silica | 0 | to 10 |
| 29 | Borosilicate glass | 0 | to 99.65 |
| 30 | Fumed synthetic silica | 0 | to 99.65 |
| 31 | Strontium glass | 0 | to 99.65 |
| 32 | Titanium dioxide | 0 | to 0.15 |
| 33 | Tinting agent (e.g., iron oxides) | 0 | to 5 |
| 34 | A-174 silane | 0 | to 6.0 |
| 35 | Peroxide curing agent | | |
| 36 | (e.g. benzoyl peroxide) | 0.30 | to 10 |
| 37 | Glacial acetic acid | 0.02 | to 0.17 |
| 38 | | | |

1 EXAMPLE 142 Paste-Powder System

3

4 Paste:

| 5 | <u>Ingredients</u> | <u>Percentage by Weight</u> |
|----|--------------------------|-----------------------------|
| 6 | Ethoxylated bisphenol-A- | |
| 7 | dimethacrylate | 63.40% |
| 8 | 2,3-Bornanediol | 0.056% |
| 9 | Ethyl-4-dimethylamino | |
| 10 | benzoate | 3.1% |
| 11 | Fumed silica | 16.05% |
| 12 | Barium glass | 16.59% |
| 13 | Titanium dioxide | 00.05% |
| 14 | Yellow iron oxide | 00.16% |
| 15 | Butylated hydroxytoluene | 0.005% |
| 16 | Glacial acetic acid | 0.004% |
| 17 | 2-Hydroxy-4-methoxy | |
| 18 | benzophenone | 0.585% |

19

20 Powder:

| 21 | <u>Ingredients</u> | <u>Percentage by Weight</u> |
|----|--------------------|-----------------------------|
| 22 | Fumed silica | 86.07% |
| 23 | Benzoyl peroxide | 8.60% |
| 24 | A-174 silane | 5.16% |
| 25 | Acetic acid | 0.17% |

26

27 When a small amount (10% by weight) of the powder
28 is added to the paste, the resulting heavy paste has a
29 working time of over 20 minutes. When so mixed and exposed
30 to the Visar curing light for 30 seconds, the depth of
31 cure measured at least 4.50 mm. Diametral tensile strength
32 was 5000 psi.

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1 EXAMPLE 152 Paste-Powder System

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4 Paste:

| 5 | <u>Ingredients</u> | <u>Percentage by Weight</u> |
|----|---------------------------|-----------------------------|
| 6 | Bis-GMA | 9.74% |
| 7 | Triethylene glycol | |
| 8 | dimethacrylate | 6.49% |
| 9 | 2,3-Bornanediol | 0.03% |
| 10 | Ethyl-4-dimethylamino | |
| 11 | benzoate | 0.76% |
| 12 | Barium glass | 24.52% |
| 13 | Lithium aluminum silicate | 57.21% |
| 14 | A-174 silane | 1.23% |
| 15 | Glacial acetic acid | 0.02% |

16

17 Powder:

| 18 | <u>Ingredients</u> | <u>Percentage by Weight</u> |
|----|---------------------------|-----------------------------|
| 19 | Barium glass | 29.05% |
| 20 | Lithium aluminum silicate | 67.78% |
| 21 | A-174 silane | 1.45% |
| 22 | Benzoyl peroxide | 1.696% |
| 23 | Glacial acetic acid | 0.024% |

24

25 The paste and powder are mixed at a weight ratio
26 of 100:5, paste:powder. When so mixed and exposed to a
27 Visar curing unit for 30 seconds, the depth of cure was
28 5.40 mm. The time to obtain a 12 mm cure was 25 minutes.
29 The diametral tensile strength was 7090 psi.

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1 EXAMPLE 162 Paste-Powder System

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4 Paste:5 IngredientsPercentage by Weight

| | | |
|----|---------------------------|--------|
| 6 | Ethoxylated bisphenol-A- | |
| 7 | dimethacrylate | 12.98% |
| 8 | Triethylene glycol | |
| 9 | dimethacrylate | 3.25% |
| 10 | 2,3-Bornanedione | 0.03% |
| 11 | Ethyl-4-dimethylamino | |
| 12 | benzoate | 0.76% |
| 13 | Barium glass | 24.52% |
| 14 | Lithium aluminum silicate | 57.21% |
| 15 | A-174 silane | 1.23% |
| 16 | Glacial acetic acid | 0.02% |

17

18 Powder:19 IngredientsPercentage by Weight

| | | |
|----|---------------------------|--------|
| 20 | Barium glass | 29.05% |
| 21 | Lithium aluminum silicate | 67.78% |
| 22 | A-174 silane | 1.45% |
| 23 | Benzoyl peroxide | 1.696% |
| 24 | Glacial acetic acid | 0.024% |

25

26 The paste and powder are mixed together at a
27 weight ratio of 100:5, paste:powder. When so mixed and
28 exposed to the output from a Visar curing unit for 30
29 seconds, the depth of cure was 5.15 mm. The time to a 12
30 mm cure was 35 minutes. The diametral tensile strength was
31 5250 psi.

32

33 Gel-Powder Systems

34 Using powder like that used in the powder-liquid
35 system but employing a gel instead of a liquid, a general
36 formulation for these systems may be as follows:

37

38

| | | |
|---|---------------------|-----------------------------|
| 1 | <u>Gel:</u> | |
| 2 | <u>Ingredients</u> | <u>Percentage by Weight</u> |
| 3 | Resin | 49 to 80.4 |
| 4 | Filler | 49 to 10.3 |
| 5 | A-174 silane | 0 to 1.25 |
| 6 | Exciplex-forming | |
| 7 | photoinitiator | 2 to 8 |
| 8 | Glacial acetic acid | 0 to 0.05 |

| | | |
|----|---------------------|-----------------------------|
| 9 | | |
| 10 | <u>Powder:</u> | |
| 11 | <u>Ingredients</u> | <u>Percentage by Weight</u> |
| 12 | Filler | 99.95 to 93.786 |
| 13 | A-174 silane | 0 to 1.50 |
| 14 | Peroxide | 0.05 to 4.69 |
| 15 | Glacial acetic acid | 0 to 0.024 |
| 16 | | |

17 The mixture may vary from about one part of powder
18 to twenty parts of gel to about three parts of powder to
19 one part of gel.

20 . More specifically, while adhering to the general
21 formulation above, the system may use individual
22 ingredients as follows:

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- 40 -

1 Gel:2 IngredientsPercent by Weight

| | | | |
|----|--|---|---------|
| 3 | | | |
| 4 | Bis-GMA | 0 | to 72 |
| 5 | Ethoxylated bisphenol-A-dimethacrylate | 0 | to 90 |
| 6 | Ethylene glycol dimethacrylate | 0 | to 54 |
| 7 | Diethylene glycol dimethacrylate | 0 | to 54 |
| 8 | Triethylene glycol dimethacrylate | 0 | to 54 |
| 9 | Polyethylene glycol dimethacrylate | 0 | to 54 |
| 10 | Barium glass | 0 | to 15 |
| 11 | Lithium aluminum silicate | 0 | to 50 |
| 12 | Flint silica | | to 5. |
| 13 | Borosilicate glass | 0 | to 50 |
| 14 | Fumed synthetic silica | 0 | to 50 |
| 15 | Strontium glass | 0 | to 50 |
| 16 | Quartz | 0 | to 50 |
| 17 | Titanium dioxide | 0 | to 1 |
| 18 | Tinting agents (e.g., iron oxides) | 0 | to 5 |
| 19 | A-174 Silane | 0 | to 1.25 |
| 20 | Exciplex-forming photoinitiators | 2 | to 8 |
| 21 | Glacial acetic acid | 0 | to 0.05 |

23 Powder:24 IngredientsPercent by Weight

| | | | |
|----|-----------------------------------|------|----------|
| 25 | | | |
| 26 | Barium glass | 0 | to 30 |
| 27 | Lithium aluminum silicate | 0 | to 99.95 |
| 28 | Flint silica | 0 | to 10 |
| 29 | Borosilicate glass | 0 | to 99.95 |
| 30 | Fumed synthetic silica | 0 | to 99.95 |
| 31 | Strontium glass | 0 | to 99.95 |
| 32 | Titanium dioxide | 0 | to 1.50 |
| 33 | Tinting agent (e.g., iron oxides) | 0 | to 5 |
| 34 | A-174 silane | 0 | to 1.50 |
| 35 | Peroxide curing agent | | |
| 36 | (e.g. benzoyl peroxide) | 0.05 | to 4.69 |

1 EXAMPLE 172 Gel-Powder System

3

4 Gel:5 IngredientsPercentage by Weight

6

7

Ethoxylated bisphenol-A-

8

dimethacrylate

76.40%

9

2,3-Bornanediol

0.06%

10

Ethyl-4-dimethylamino

11

benzoate

2.28%

12

Fumed silica

8.30%

13

Barium glass

3.831%

14

Lithium aluminum silicate

8.938%

15

A-174 silane

0.188%

16

Glacial acetic acid

0.003%

17

18

Powder:

19

20 The powder is the same as that of Example 16. The
21 powder and gel are mixed together in a weight ratio of
22 3:1, powder to gel. When exposed to a visible light dental
23 curing unit for 30 seconds, the material cured to a depth
24 of 4.90 mm. Under normal room fluorescent lighting, the
25 paste had a workable time of approximately 35 minutes. The
26 diametral tensile strength was 5800 psi.

26

27 EXAMPLE 1828 Gel-Powder System

29

30

Gel:

31

IngredientsPercentage by Weight

32

Ethoxylated bisphenol-A-

33

dimethacrylate

76.34%

34

2,3-Bornanediol

0.14%

35

Ethyl-4-dimethylamino

36

benzoate

2.28%

37

Fumed silica

21.24%

38

1 Powder:

2 The powder is the same as that used in example 16
3 The powder and gel are mixed in a ratio of 3:1, powder to
4 gel. When, exposed to a visible light dental curing unit
5 30 seconds, the material cured to a depth of 5.40 mm.
6 Under normal fluorescent lighting, the paste has a
7 workable time of 25 minutes. The diametral tensile
8 strength was 7090 psi.

9
10 This restorative system may be used in the repair
11 of fractured porcelain material, natural teeth, or in any
12 other intra-oral situation where a resin material is
13 desired to replace or simulate tooth structure that is
14 capable of being polymerized by visible light and having
15 the process continue after the light is removed.

16 Also, this restorative system, which is essenti-
17 ally a light-cured system, achieves uniform polymerization
18 within thirty minutes to one hour after insertion in the
19 patient's mouth, even though variable amounts of light be
20 exposed to the polymerizing resin.

21 This system eliminates the color changes that tend
22 to occur when certain resins mixed with curing resins are
23 exposed to ultra-violet or visible light.

24 To those skilled in the art to which this
25 invention relates, many changes in construction and widely
26 differing embodiments and applications of the invention
27 will suggest themselves without departing from the spirit
28 and scope of the invention. The disclosures and the
29 descriptions herein are purely illustrative and are not
30 intended to be in any sense limiting.

31 What is claimed is:

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1 1. A filled-resin composition useful for porcelain
2 repair and as a dental composite and therefore made up of
3 non-toxic materials, comprising:

4 a methacrylate functional resin usable in dental
5 composites,

6 powdered filler-colorant therein,

7 at least one photoinitiator for said resin in an
8 amount sufficient to initiate polymerization and complete
9 it in depth within about half a minute when exposed to a
10 visible-light output of at least 5,000 foot candles, said
11 photoinitiator being an exciplex of (1) either
12 2,3-bornanedione or benzil and (2) either ethyl-4-dimethyl
13 amino benzoate or ethyl-2-dimethyl amino benzoate, and

14 at least one accelerator-free peroxide curing
15 agent for said resin in an effective amount for completing
16 polymerization within about an hour of any portion of said
17 resin not receiving sufficient light to effectuate
18 complete cure before then.

19

20 2. The composition of claim 1 wherein said photo-
21 initiator is 2,3-bornanedione with ethyl-4-dimethyl amino
22 benzoate.

23

24 3. The composition of claim 1 wherein said photo-
25 initiator is 2,3-bornanedione with ethyl-2-dimethyl amino
26 benzoate.

27

28 4. The composition of claim 1 wherein said photo-
29 initiator is benzil with ethyl-4-dimethyl amino benzoate.

30

31 5. The composition of claim 1 wherein said photo-
32 initiator is benzil with ethyl-2-dimethyl amino benzoate.

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- 1 6. A two-part system for making a filled
2 methacrylate-functional resin composition by mixture of
3 the two parts, comprising:
4 first part: dental-type filler powder with an
5 accelerator-free peroxide curing agent for said resin,
6 second part: dental-type methacrylate-functional
7 resin with photoinitiator therefor,
8 said photoinitiator being an exciplex of (1)
9 either 2,3-bornanedione or benzil and (2) either ethyl-
10 4-dimethyl amino benzoate or ethyl-2-dimethyl amino
11 benzoate, in an amount sufficient to initiate
12 polymerization and complete it within about half a minute
13 after the first part and second parts are mixed and then
14 exposed during cure to at least 5,000 foot candles visible
15 light,
16 said peroxide curing agent being present in an
17 amount effective to complete cure of any resin portion not
18 sufficiently exposed to said light within about an hour.
19
20 7. The system of claim 6 wherein the first part is
21 in the form of a powder.
22
23 8. The system of claim 7 wherein the second part
24 is in the form of a liquid.
25
26 9. The system of claim 8 wherein the powder to
27 liquid weight ratio is from about 1:1 to about 4:1.
28
29 10. The system of claim 7 wherein the second part
30 is in the form of a gel and also contains some filler.
31
32 11. The system of claim 10 wherein the powder-gel
33 weight ratio is from about 1:20 to about 3:1.
34
35 12. The system of claim 6 wherein both the first
36 and second parts are in paste form, both containing
37 substantial amounts of filler.
38

1 13. The system of claim 12 wherein the first and
2 second parts are so formulated to enable mixture of equal
3 parts by weight at the time of use.

4
5 14. A porcelain-repair and dental composite
6 composition of matter consisting essentially of
7 a powder component consisting essentially by
8 weight of:

9
10 Dental filler-colorant material 99.85% to 97.7%
11 Gamma-methacryloxy propyl
12 trimethoxy silane 0.10% to 1.55%
13 Peroxide curing agent 0.05% to 0.70%
14 Glacial acetic acid 0 to 0.05%
15
16 and a liquid component consisting essentially, by weight
17 of:

18 a methacrylate-functional resin
19 suitable for use in dental
20 composites 99.3% to 82%
21 exciplex-forming photoinitiator
22 for said resin 0.7% to 18%

23
24 said photoinitiator an exciplex of either (1) 2,3-
25 bornanediol or benzil and (2) either ethyl-4-dimethyl
26 amino benzoate or ethyl-2-dimethyl amino benzoate, and
27 said powder and resin being mixed together in a weight
28 ratio between 1:1 and 4:1 of powder to liquid.

29
30 15. The porcelain-repair and dental composite
31 composition of matter of claim 14 wherein:
32 said filler-colorant consists essentially by
33 weight of ingredients totaling as in claim 14 and selected
34 from the group consisting of:

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| | | |
|---|---------------------------|--------------|
| 1 | Barium glass | 0% to 30% |
| 2 | Lithium aluminum silicate | 0% to 99.85% |
| 3 | Flint silica | 0% to 10% |
| 4 | Borosilicate glass | 0% to 99.85% |
| 5 | Fumed synthetic silica | 0% to 99.85% |
| 6 | Quartz | 0% to 99.85% |
| 7 | Custer feldspar | 0% to 10% |

8
9 said powder component also including, in addition
10 to the silane, the peroxide curing agent, and the glacial
11 acetic acid:

| | | |
|----|------------------|-------------|
| 12 | | |
| 13 | Titanium dioxide | 0% to 0.15% |
| 14 | Metal salts | 0% to 5.00% |

15
16 said methacrylate-functional resin totaling as in
17 claim 14 and consisting essentially by weight of
18 ingredients:

| | | |
|----|------------------------------------|-------------|
| 19 | | |
| 20 | Bis-GMA | 0% to 80% |
| 21 | Ethoxylated bisphenol-A- | |
| 22 | dimethacrylate | 0% to 99% |
| 23 | Ethylene glycol dimethacrylate | 0% to 60% |
| 24 | Diethylene glycol dimethacrylate | 0% to 60% |
| 25 | Triethylene glycol dimethacrylate | 0% to 60% |
| 26 | Polyethylene glycol dimethacrylate | 0% to 60% |
| 27 | Exciplex forming photoinitiator | 0.7% to 18% |

28
29 16. The composition or system of any one of claims
30 1, 6, and 14 wherein said peroxide curing agent is benzoyl
31 peroxide.

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1 17. A porcelain-repair and dental composite
2 restorative material consisting essentially of:

3 (a) a powder component, consisting essentially of a
4 powdered dental filler-colorant, with a
5 powdered peroxide curing agent in an amount
6 between 0.05% and 1% by weight of said powder
7 component, and

8 (b) a liquid component, consisting essentially of
9 (1) a methacrylate-functional resin suitable
10 for use in dental composites in an amount
11 of 84-96% by weight of said liquid
12 component, and

13 (2) a photoinitiator for said resin consist-
14 ing of an exciplex incorporating as one
15 ingredient either ethyl-4-dimethyl amino
16 benzoate or ethyl-2-dimethyl amino
17 benzoate in an amount of about 0.7 to 10%
18 by weight of said liquid component, the
19 other ingredient being either 2,3-
20 bornanediene or benzil and present in an
21 amount of 0.01 - 8%, by weight of said
22 liquid component, for a total photoiniti-
23 ator amount by weight of said liquid
24 component of about 0.7 to 18%,

25 said powder and liquid components being mixed
26 together just before use in a weight ratio of from 2:1 to
27 3-1/2 powder to liquid.

28

29 18. The restorative material of claim 17, wherein
30 said powder component, by weight of said powder component
31 contains:

| | |
|------------------------------|----------|
| 32 Barium glass | 23 - 30% |
| 33 Lithium aluminum silicate | 54 - 70% |
| 34 Flint silica | 1 - 70% |

35

36 for a total filler content of about 97-1/2 to
37 99.85%.

38

1 19. The restorative material of claim 17 wherein
2 said powder component also contains glacial acetic acid
3 and gamma-methacryloxy propyl trimethoxy silane.
4

5 20. The restorative material of claim 17 wherein
6 said glacial acetic acid is present in an amount of about
7 0.001 - 0.05%, by weight of said powder component, and
8 said silane is present in an amount of about 1/10 of 1% to
9 about 1-1/2% by weight of said powder component.
10

11 21. The restorative material of claim 17 wherein
12 said resin is ethoxylated bisphenol-A-dimethacrylate in an
13 amount of about 82 to 99.3% by weight of said liquid
14 component.
15

16 22. The restorative material of claim 17 wherein
17 said resin is a mixture, by weight of said liquid
18 component, of about 60-84% ethoxylated bisphenol-A-
19 dimethacrylate and about 40-16% triethylene glycol
20 dimethacrylate.
21

22 23. The restorative material of claim 17 wherein
23 said resin is a mixture, by weight of said liquid
24 component, of about 55% Bis-GMA and about 36% of
25 triethanol glycol dimethacrylate.
26

27 24. The restorative material of claim 17 employing
28 2,3-bornanedione in amounts by weight of said liquid
29 component of 0.02 - 0.2%.
30

31 25. The restorative material of claim 17 wherein
32 said liquid component also includes BHT in an amount of
33 about 0.02% by weight of said liquid component.
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1 26. A two-paste system for porcelain and dental
2 restoration, said pastes being mixed together at the time
3 of use in substantially equal amounts by weight,

4 both pastes containing methacrylate-functional
5 resin suitable for use in dental components and dental
6 filler material an an amount totaling over 95% thereof by
7 weight of each paste,

8 one said paste containing a peroxide curing agent
9 for said resin in an amount of about 0.1% to 1.0% by
10 weight of that paste,

11 the other said paste containing an exciplex
12 visible-light-reactive photoinitiator for said resin in
13 an amount of about 1 to 3.5% by weight of that paste, said
14 exciplex being a mixture of (1) either 2,3-bornanedione or
15 benzil and (2) either ethyl-4-dimethyl amino benzoate or
16 ethyl-2-dimethyl amino benzoate.

17
18 27. The system of claim 26 in which each paste
19 also contains gamma-methacryloxy propyl trimethoxy silane
20 in an amount of about 0.05 to 1.2% by weight of each
21 paste.

22
23 28. The system of claim 26 in which at least one
24 of the pastes also contains glacial acetic acid in an
25 amount of at least 0.0015% by weight of that paste.

26
27 29. The system of claim 26 wherein said resin is
28 ethoxylated bisphenol-A-dimethacrylate.

29
30 30. The system of claim 26 wherein said resin is
31 present in the peroxide-containing paste in an amount of
32 about 14 - 40% and is present in the exciplex-containing
33 paste in an amount of 14-36%.

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1 31. The system of claim 26 wherein said filler is
2 chosen from (a) the group consisting of strontium glass
3 and a mixture of barium glass with lithium aluminum
4 silicate, and also includes fumed silica.

5
6 32. The system of claim 31 wherein the filler
7 comprises, by weight of each paste about 1% of fumed
8 silica and about 80% of strontium glass.

9
10 33. The system of claim 31 wherein the filler
11 comprises, by weight of each paste, about 1% of fumed
12 silica, about 23-25% of barium glass, and about 54-58% of
13 lithium aluminum silicate.

14
15 34. A paste-powder system for use in dental and
16 porcelain restoration, the paste and powder being mixed at
17 the time of use at a ratio of paste to powder of about
18 10:1 to 20:1,

19 said paste comprising the mixture of methacrylate-
20 functional dental resin and powdered dental filler in a
21 total amount of about 96-99% by weight of the paste and
22 having an exciplex, visual-light reactive photoinitiator,

23 said powder consisting essentially of a dental
24 filler and a peroxide curing agent for the resin in an
25 amount of about 0.3% - 9% of the powder,

26 said exciplex being made up of

27 (a) 2,3-bornanedione in an amount of about 0.03%
28 to 0.06% by weight of said paste and,

29 (b) either ethyl-4-dimethyl amino benzoate or
30 ethyl-2-dimethyl amino benzoate in an amount of about 0.75
31 to 3.25% by weight of said paste.

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1 35. The system of any of claims 1, 6, 17 and 34
2 wherein said resin is selected from the group consisting
3 of ethoxylated bisphenol-A-dimethacrylate, bis-GMA a
4 mixture thereof with an ethylene glycol dimethacrylate,
5 and a mixture of bis-GMA with an ethylene glycol
6 dimethacrylate.

7
8 36. The system of claim 34 wherein the resin is
9 from 16-64% ethoxylated bisphenol-A-dimethacrylate, by
10 weight of said paste.

11
12 37. The system of claim 34 wherein the resin is a
13 mixture of about 13% ethoxylated bisphenol-A-
14 dimethacrylate and about 3-1/4% of triethylene glycol
15 dimethacrylate, both by weight of said resin.

16
17 38. The system of claim 34 wherein the resin is a
18 mixture of about 10% bis-GMA and about 6-1/2% triethylene
19 glycol dimethacrylate, both by weight of said resin.

20
21 39. The system of claim 34 wherein at least the
22 powder contains gamma-methacryloxy propyl trimethoxy
23 silane, in an amount of about 1.25 to 5.25% by weight of
24 its component.

25
26 40. The system of claim 34 wherein at least the
27 powder contains glacial acetic acid in an amount of about
28 0.02 to 0.2% by weight of its component.

29
30 41. A gel-powder system for use in dental and
31 porcelain restoration, the gel and powder being mixed at
32 the time of use for cure by visible light, in a ratio of
33 about 20:1 to 1:3 of gel to powder,

34 the gel consisting essentially of about 3/4
35 methacrylate-functional dental resin and about 1/4 dental
36 filler to a total amount of about 93-98% by weight of said
37 gel and an exciplex, visible-light-reactive photoiniti-
38

1 ator having two ingredients, one of which is either ethyl-
2 4-dimethyl amino benzoate or ethyl-2-dimethyl amino
3 benzoate,

4 said powder consisting essentially of a dental
5 filler and an accelerator-free peroxide curing agent for
6 said resin in an amount of about 0.1% - 10% by weight of
7 said powder,

8 said exciplex being made up of

9 (a) 2,3-bornanedione in an amount of about 0.005
10 to 0.15% by weight of said gel and,

11 ~~(b) either ethyl-4-dimethyl amino benzoate or~~
12 ~~ethyl-2-dimethyl amino benzoate in an amount of about 2.0~~
13 ~~to 8% by weight of said gel.~~

14

15 42. The system of claim 41 wherein said resin is
16 ethoxylated bisphenol-A-dimethacrylate.

17

18 43. The system or material of claim 17 or claim 41
19 wherein said filler for the powder component is selected
20 from the group consisting of barium glass, strontium
21 glass, lithium aluminum silicate, flint silica and
22 mixtures of the members of this group with each others.

23

24 44. The system or material of claim 41 wherein
25 said filler for the powder component is a mixture of
26 barium glass, lithium aluminum silicate and flint silica.

27

28 45. The system of claim 41 wherein said filler for
29 the powder component contains, by weight of the powder,
30 26-30% barium glass, 62-70% lithium aluminum silicate and
31 1-10% flint silica.

32

33 46. The system of claim 34 or claim 41 wherein
34 said filler for the gel component is fumed silica.

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1 47. The system of claim 34 or claim 41 wherein
2 said filler for the gel component is a mixture of barium
3 glass and lithium aluminum silicate.
4

5 48. The system of claim 41 wherein said filler for
6 the gel component comprises, by weight of the gel, about
7 2-5% barium glass, about 5-10% lithium aluminum silicate
8 and about 7-10% fumed silica.
9

10 49. The system of claim 41 wherein at least the
11 powder component contains gamma-methacryloxy propyl
12 trimethoxy silane, in an amount of about 0.05 to 2.0% by
13 weight of its component.
14

15 50. The system of claim 41 wherein at least the
16 powder component contains glacial acetic acid, in an
17 amount of about 0.01 to 0.05% by weight of its component.
18

19 51. A method for repairing porcelain or teeth,
20 comprising

21 mixing together under ordinary indoor lighting
22 conditions, a methacrylate functional resin usable in
23 dental composites, powdered dental filler-colorant, at
24 least one photoinitiator for said resin in an amount
25 sufficient to initiate polymerization and complete it in
26 depth within about half a minute when exposed to a
27 visible-light output of at least 5000 foot-candles, said
28 photoinitiator being an exciplex of (1) either
29 2,3-bornanedione or benzil and (2) either ethyl-4-dimethyl
30 amino benzoate or ethyl-2-dimethyl amino benzoate, and at
31 least one accelerator-free peroxide curing agent for said
32 resin in an effective amount for completing polymerization
33 within about an hour of any portion of said resin not
34 receiving sufficient light to effect complete cure before
35 then,

36 emplacing the mixture within a few minutes of the
37 mixing, and
38

1 curing at least a substantial portion of the
2 emplaced mixture in situ for one half-minute under intense
3 visual-light illumination of at least 5000 foot-candles,
4 any resin then uncured by light being cured within about
5 another hour by said peroxide curing agent.
6

7 52. The method of claim 51 wherein the resin is at
8 least one resin chosen from the group consisting of
9 ethoxylated bisphenol-A-dimethacrylate, bis-GMA, and an
10 adduct of 2,2'-propane bis [3-(4-phenoxy)-1, 2-hydroxy
11 propane-1 methacrylate] and mono- or di- isocyanate.
12

13 53. A method for preparing a storable filled-resin
14 composition useful for porcelain repair and as a dental
15 composite, comprising:

16 mixing a methacrylate functional resin usable in
17 dental composites with at least one photoinitiator for
18 said resin, in an amount sufficient to initiate polymeri-
19 zation and complete it in depth within about half a minute
20 when exposed to a visible-light output of at least 5000
21 foot-candles, said photoinitiator being an exciplex of (1)
22 either 2,3-bornanedione or benzil and (2) either ethyl-4-
23 dimethyl amino benzoate or ethyl-2-dimethyl amino
24 benzoate,

25 storing the resin-photoinitiator mixture in an
26 opaque container,

27 coating a powdered dental filler-colorant with at
28 least one accelerator-free peroxide curing agent for said
29 resin in an effective amount substantially less than
30 stoichiometric, and sufficient to effect completion of
31 polymerization within about an hour of any portion of said
32 resin not receiving sufficient light during said half a
33 minute,

34 storing said filler-colorant and peroxide mixture,
35 and
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- 55 -

1 at the time of use, mixing said resin-
2 photoinitiator mixture with said peroxide-coated filler-
3 colorant under ordinary indoor illumination.
4

5 54. A method for repairing porcelain or teeth,
6 comprising

7 preparing under ordinary indoor lighting
8 conditions, a liquid mixture consisting essentially of a
9 methacrylate functional resin usable in dental composites,
10 and at least one photoinitiator for said resin in an
11 amount sufficient to initiate polymerization and complete
12 it in depth within about half a minute when exposed to a
13 visible-light output of at least 5000 foot-candles, said
14 photoinitiator being an exciplex of (1) either 2,3-
15 bornanediene or benzil and (2) either ethyl-4-dimethyl
16 amino benzoate or ethyl-2-dimethyl amino benzoate,

17 preparing under ordinary indoor lighting
18 conditions a powdered mixture of powdered dental filler-
19 colorant and at least one accelerator-free peroxide curing
20 agent for said resin in an effective amount for completing
21 polymerization within about an hour of any portion of said
22 resin not receiving sufficient light to effect complete
23 cure before then,

24 mixing said powder mixture and said liquid mixture
25 together under ordinary indoor lighting conditions in a
26 powder to liquid ratios of about 1:1 to 4:1 just prior to
27 use to provide a repair mixture,

28 emplacing the repair mixture within a few minutes
29 of the mixing, and

30 curing at least a substantial portion of the
31 emplaced mixture in situ for one half-minute under intense
32 visual-light illumination of at least 5000 foot-candles,
33 any resin then uncured by light being cured within the
34 next half hour by said peroxide curing agent.

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1 55. The method of claim 54 wherein said exciplex
2 constitutes about 0.7% to about 18% by weight of said
3 liquid mixture and said peroxide constitutes about 0.1 to
4 about 0.8% of said powder mixture.

5
6 56. The method of claim 54 having the step in
7 between preparing and mixing of storing said powder in a
8 container and of storing said liquid in an opaque
9 container.

10
11 57. A method for repairing porcelain or teeth,
12 comprising:

13 providing under ordinary indoor lighting
14 conditions first paste consisting essentially of a
15 methacrylate functional resin usable in dental composites,
16 a powdered dental filler-colorant, and at least one photo-
17 initiator for said resin in an amount sufficient to
18 initiate polymerization and complete it in depth within
19 about half a minute when exposed to a visible-light output
20 of at least 5000 foot-candles, said photoinitiator being
21 an exciplex of (1) either 2,3-bornanedione or benzil and
22 (2) either ethyl-4-dimethyl amino benzoate or ethyl-2-
23 dimethyl amino benzoate,

24 providing a under ordinary indoor lighting
25 conditions second paste consisting essentially of a
26 methacrylate functional resin usable in dental composites,
27 a powdered dental filler colorant, and at least one
28 accelerator-free peroxide curing agent for said resin in
29 an effective amount for completing polymerization within
30 about an hour of any portion of said resin not receiving
31 sufficient light to effective complete cure before then,

32 mixing under ordinary indoor lighting conditions
33 said first and second pastes in approximately the same
34 amount of each, to form a paste mixture,

35 emplacing the paste mixture within a few minutes
36 of the mixing, and

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1 curing at least a substantial portion of the
2 emplaced mixture in situ for one half-minute under intense
3 visual-light illumination of at least 5000 foot-candles,
4 any resin then uncured by light being cured within about
5 an hour thereafter by said peroxide curing agent.

6
7 58. The method of claim 57 wherein said first
8 paste, at least, is prepared long in advance and compris-
9 ing the step of storing said first paste in an opaque
10 container until said mixing step.

11
12 59. The method of claim 57 in which said exciplex
13 constitutes about 1 to 4% by weight of said first paste
14 and said peroxide constitutes about 0.1 to 1.0% by weight
15 of said second paste.

16
17 60. A method for repairing porcelain or teeth,
18 comprising:

19 mixing together under ordinary indoor lighting
20 conditions a paste consisting essentially of a methacry-
21 late functional resin usable in dental composites,
22 powdered dental filler-colorant, at least one photoiniti-
23 ator for said resin in an amount sufficient to initiate
24 polymerization and complete it in depth within about half
25 a minute when exposed to a visible-light output of at
26 least 5000 foot-candles, said photoinitiator being an
27 exciplex of (1) an aromatic ketone or acetal and (2)
28 either ethyl-4-dimethyl amino benzoate or ethyl-2-dimethyl
29 amino benzoate,

30 mixing together under ordinary indoor lighting
31 conditions a powder consisting essentially of a powdered
32 dental filler-colorant and at least one accelerator-free
33 peroxide curing agent for said resin in an effective
34 amount for completing polymerization within about one-half
35 hour of any portion of said resin not receiving sufficient
36 light to effectively complete cure before then,

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1 mixing together under ordinary indoor lighting
2 conditions, immediately before use, said paste and said
3 powder in a ratio of paste to powder of about 20:1 to
4 10:1, to form a thick paste,

5 emplacing the thick paste within a few minutes of
6 the mixing, and

7 curing at least a substantial portion of the
8 emplaced mixture in situ for one half-minute under intense
9 visual-light illumination of at least 5000 foot-candles,
10 any resin then uncured by light being cured within about
11 an hour thereafter by said peroxide curing agent.

12
13 61. The method of any of claims 51, 53, 54, 57, or
14 60 wherein said peroxide curing agent is benzoyl
15 peroxide.

16
17 62. The method of claim 60 wherein said mixing of
18 said paste is done well in advance of use including the
19 step of storing said paste in an opaque container prior to
20 said mixing of the powder with the pad.

21
22 63. The method of claim 60 wherein said exciplex
23 constitutes about 0.7 to 4% of said paste and said
24 peroxide constitutes about 0.3 to about 10% of said
25 powder.

26
27 64. A method for repairing porcelain or teeth,
28 comprising:

29 mixing together under ordinary indoor lighting
30 conditions,

31 a gel consisting essentially of about 3/4
32 methacrylate-functional dental resin and about 1/4 dental
33 filler to a total amount of about 93 to 97-1/2% by weight
34 of the gel and an exciplex, visible-light-reactive photo-
35 initiator having two ingredients, one of which is either

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1 ethyl-4-dimethyl amino benzoate or ethyl-2-dimethyl amino
2 benzoate, in a total amount of about 2% to 8% by weight of
3 the gel,

4 with a powder consisting essentially of a filler
5 and an accelerator free peroxide curing agent for the
6 resin in an amount of about 0.1 - 5% by weight of the
7 powder,

8 in a ratio of about 20:1 to 1:3 of gel to powder.
9

10 65. The method of claim 64 wherein the resin is
11 ethoxylated bisphenol-A-dimethacrylate.
12

13 66. The method of claim 64 wherein the filler for
14 the gel component is fumed silica.
15

16 67. The method of claim 64 wherein the filler for
17 the gel component comprises, by weight of the gel, about
18 2-5% barium glass, about 5-10% lithium aluminum silicate
19 and about 7-10% fumed silica.
20

21 68. The method of claim 64 wherein the exciplex is
22 made up of

23 (a) either 2,3-bornanedione or 2-isopropyl
24 thioxanthone in an amount of about 0.005 to 0.15% by
25 weight of the gel and,

26 (b) either ethyl-4-dimethyl amino benzoate or
27 ethyl-2-dimethyl amino benzoate in an amount of about 2.0
28 to 7.5% by weight of the gel.
29

30 69. The method of claim 64 wherein the filler for
31 the powder component is selected from the group consisting
32 of barium glass, lithium aluminum silicate, flint silica
33 and mixtures of the members of this group with each other.
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1 70. The method of claim 64 wherein the filler for
2 the powder component contains, by weight of the powder,
3 16-30% barium glass, 62-70% lithium aluminum silicate and
4 1-10% flint silica.
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